MODELING STUDY OF PCBs IN THE HOUSATONIC RIVER PEER REVIEW

Modeling Framework Design
Final Written Comments

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RESPONSE TO CHARGE FOR THE HYDRODYNAMIC MODELING PEER REVIEW

I. General Overview of Response

This is an ambitious project. The EPA in collaboration with GE seeks to develop and apply a predictive numerical model of PCB fate and transport in the Housatonic River. Initially this model will focus on the river reach extending for a distance of approximately 11 miles south from the confluence of the east and west branches of the Housatonic to Woods Pond (defined as the Primary Study Area (PSA)). This area, beginning just to the south of the GE manufacturing facility in Pittsfield, Massachusetts, is known to contain significant concentrations of PCBs in sediments resident within the main stem channel of the river as well as in the bordering banks and floodplain. The model is intended to assist in the development and assessment of a variety of remedial alternatives both active and passive.

The range of processes affecting the transport, fate, and biotic impact of PCBs in a river system includes a multiplicity of physical, chemical and biological factors. To accommodate this complexity the proposed model will consist of three principal sub-models; HSPF to define watershed hydrological characteristics and the resulting streamflows and selected contaminant fluxes, EFDC a hydrodynamic/sediment transport model and AQUATOX a PCB fate and bioaccumulation model. The sub-models are intended to function collaboratively and to form a relatively coherent whole with capabilities in excess of a simple summation of individual contributions.

The linking of three discrete numerical models to form a coherent unit is a complex undertaking and requires in-depth understanding of the site-specific factors affecting PCB fate and transport in the PSA both to design and implement the model and to constrain governing parameters. In the absence of such understanding it is difficult to justify the complexity of a multi unit model approach. The MFD begins, as it should, with a discussion of the conceptual model forming the basis for the proposed approach. This discussion includes consideration of selected historical data as well project specific data gathered over the past few years by EPA. In outline the development of the conceptual model appears reasonably comprehensive. Examination of the details however, indicates that the conceptual model exercise is seriously deficient with many key elements remaining to be established. Weaknesses resulting from this deficiency adversely affect all components of the MFD and call into question the need for the proposed complex modeling scheme.

The inadequacies in the details of site assessment affecting the conceptual model development appear to be primarily the result of limited data analysis and the absence of hypothesis based field sampling. With few exceptions, the majority of the sampling activities place primary emphasis on detailing the spatial distributions of PCBs, sediments, and a variety of the geomorphological characteristics of the River and adjoining watershed. There are few studies dealing with system dynamics and as a result the discussion presented of the relative importance of a variety of factors including stream meandering, the floodplain as a source or sink, bed-load transport, and implications with respect to the long term sequestering of PCBs is largely conjectural. This leaves entirely too many model parameters to be user specified and will ultimately limit the utility of the model as a predictive tool.

To correct this situation and to develop a basis sufficient to justify the complexity of the proposed modeling approach the Modeling Team must present a more closely reasoned conceptual model supplemented by additional field work ,as necessary. Using the extensive spatial data in combination with indications from GE regarding the annual input of PCBs to the Housatonic, the development of this model might begin with a mass balance discussion (or box model) of the amount(s) of PCB resident in the study area and probable fluxes to and through the system. Several bits of information presented to the Peer Review Panel suggest that the system is quite "leaky" and that introduced PCBs move downstream rapidly. EPA comments regarding the absence of sequestering appear to support this view. What are the implications of this response ? One might be that effective elimination of the Pittsfield source would reduce the downstream flux to near zero since all remaining reservoirs represent deep burial in equilibrium with a wide range of flow conditions. This hypothesis seemingly is in the process of being tested and needs little model support. Alternatively, one might posit that elimination of the primary source would only slow downstream flux due to the inherent instability of the multiple reservoirs. Here again is an hypothesis to be tested by field sampling following completion of the ongoing source control projects. These data may show transport time scales short compared to remedial implementation times. (i.e. before remediation/cleanup can be implemented all PCBs will have left the PSA). It's only if we believe that the variety of repositories of PCB in the study area represent continuing long-term sources that detailed modeling is justified. A mass balance review would assist in the development of a reasoned justification for the proposed model approach.

Following initial justification, the MFD should clearly present an evaluation of each of the primary factors affecting PCB fate and transport. Begin with a discussion of source(s) and the form of the contaminant (NAPL, solute,particle bound, airborne, etc.) and implications re modeling. Continue with a presentation of the transport system and the importance of all relevant factors including suspended vs. bedload, the role of the sediment column as a source/sink, biotic mediation, and the effect of storms. How will transport be affected by meandering ? How will meandering be modeled ? This may be rendered un-necessary since the mass balance discussion might indicate PCB transport time scales short compared to meandering times. Move next to the matter of floodplain dynamics and present a process based discussion of the role of this area in the transport system. Much of what is included in the MFD with respect to the floodplain is inferential and lacks specificity. Throughout include discussion of the role of each of these components as a factor controlling the flux of PCB to and up the food chain. Conclude with a summary statement describing the system that is to be represented numerically. Such a reasoned presentation would greatly increase confidence that the proposed model complexity is justified and that the resulting product will ultimately prove to be a valuable adjunct to remedial efforts.

II. Response to Peer Review Questions

In considering the foregoing general issues and evaluating the EPA documents, the Peer Review Panel shall give specific consideration to the following questions. As modeling activities proceed, additional specific questions may be identified the panel to address.

A. Modeling Framework and Data Needs

1. Do the modeling frameworks used by EPA include the significant processes affecting PCB fate, transport, and bioaccumulation in the Housatonic River; and are the descriptions of these processes in the modeling framework(s) sufficiently accurate to represent the hydrodynamics, sediment transport, PCB fate and transport, and PCB bioaccumulation in the Housatonic River?

The MFD includes consideration (or at least mention) of all significant processes affecting PCB fate and transport in the Housatonic River. The evaluation of the relative importance of these processes is, however, not well done. As a result, the component models include entirely too many user specified parameters. The modeling team should present a closely reasoned discussion of the relative importance of the variety of processes governing PCB fate and transport in the Housatonic River.

With regard to process description, the MFD provides an adequate description of the factors affecting river hydrodynamics and the combination of HSPF and EFDC appear able to accurately simulate a wide range of conditions ranging from daily average to the extreme storm event. While care must be exercised in the development of the spatial segmentation particularly with respect to floodplain areas to insure numerical stability and mass continuity I am more concerned with the physical basis for the selected scheme. e.g. What spatial resolution is required to accommodate the observed variations in sediment type and/or geomorphological form (i.e. bars, shallows, meanders). This aspect is not discussed in the MFD and it is not clear that the required field data exist to answer the question. e.g. Review provides no indication that a number of transects have been subjected to high density spatial sampling in order to permit quantitative specification of the relevant spatial scales. If such data exist a short summary should be provided in the MFD.

Moving next to the issue of sediment transport, the MFD discusses most of the processes affecting erosion, transport and deposition and presents some amount of supporting data. The subsequent development of a conceptual model of the sediment transport regime would benefit from high frequency time series observations of suspended material and bed load fluxes and finer spatial sampling scales over the vertical. It is not clear, for example why all analyses of PCB distributions began with a composite sample of the upper six (6) inches of the sediment column. Are there data to indicate that sampling at 1in increments (or some such) shows an essentially uniform vertical distribution ? Are these data supported by the radionuclide data ? The combination would have some interesting implications relative to transport.

The higher resolution time series (sampling rates of N samples/day for bedload and N samples/hour for suspended load) observations of both bed load and suspended load in combination with the radionuclide data detailing long term sedimentation rates at several locations throughout the PSA would permit quantitative definition of the structure and form of the sediment water interface, critical erosion velocities, the extent of sediment recycling, and the overall trapping efficiency of this region of the River. All represent information essential to accurate modeling of sediment fluxes. There is no indication that such data presently exist. The available time series data set is sparse and provides limited temporal resolution. The use of SEDFLUME to define critical erosion velocities provides little information on the small scale processes affecting the immediate sediment water interface and no information on the flux and recycling of high water content suspended materials resident along the interface. These latter materials can transport significant quantities of recently introduced PCBs and measurably affect the storage of the contaminants within the underlying water column. Lacking an accurate specification of the role of these materials the modeler is often forced to introduce a "transport parameter" artificially driving PCBs from the sediment column to the overlying water in quantities sufficient to satisfy mass balance requirements. The resulting construct often represents a poor substitute for reality, is open to easy criticism, and typically complicates the development of acceptable long term remedial methods.

Beyond the details of the sediment transport process, the geomorphological implications are not adequately discussed in the MFD. In particular it is not at all clear just how the model plans to treat the matter of channel meandering, bank erosion, and the dynamics of the River's bars, terraces, and benches. PCBs are observed in these latter areas with introduction apparently the result of both natural transport during high water events and man associated placement of fill. Given the complexity of some of these components a "black box" approach maybe the best that can be expected. Alternatively, some relatively simple site-specific observations may provide indication that some few or all of these components can be neglected. Of these three for example, it may be that only bar and terrace dynamics need be considered since the transport time scales affecting meandering or bank erosion are long compared to those characterizing the majority of the PCB transport.

The modeling of sediment transport to and through the PSA is intended to directly complement evaluations of PCB flux and definition of the longterm potential of the area as a contaminant reservoir and continuing source to adjoining and downstream regions of the Housatonic River. Central to the specification of PCB flux is the definition of the source(s) presently supplying the contaminant burden crossing the upstream boundary of the PSA. The MFD provides relatively little information on source flux and contaminant form (dissolved, particulate, aerosol, NAPL) and no discussion of manner in which the ongoing mitigation efforts by GE and those planned in the near future by EPA will affect source characteristics.

2. ***Based upon the technical judgment of the Peer Review Panel:***
3.

a. Are the modeling approaches suitable for representing the relevant external force functions (e.g.. hydraulic flows, solids and PCB loads, initial sediment conditions, etc.), describing quantitative relationships among those functions, and developing quantitative relationships between those functions and PCB concentrations in environmental media (e.g., water column, sediments, fish and other biota, etc.)?

The approach outlined in the MFD appears sufficient to accurately define streamflows and the associated suspended material flux crossing the upstream boundary of the model. The MFD provides no indication of just how the bedload flux is to be incorporated. One might suspect that it will be defined using measurements of bedload obtained at a variety of streamflows. These measurements are yet to be obtained.

Although not specifically defined in the MFD it is my understanding that the PCB flux crossing the upstream boundary will not be a modeled parameter but rather will be specified using EPA field data obtained over the past few years. The adequacy of this approach must be carefully demonstrated. In addition a clear indication of just how this specification is to be handled following completion of the ongoing source remediation efforts in Pittsfield. As stated on a number of occasions, the remedial efforts represent an experiment in progress and full advantage should be taken of the opportunity to document system response to a reduction in contaminant flux.

b. ***Are the models adequate for describing the interactions between the floodplains and the river?***

Nowhere is the transport system affecting floodplain PCB concentrations discussed making it difficult to evaluate model adequacy. In particular, the role of vegetation, with the possible exception of frictional effects, is ignored. It would appear that the floodplain is to be treated simply as a sediment deposit with entrained PCBs. Displacement is fundamentally a sediment transport process and is to be simulated using some estimated critical erosion characteristics with boundary shear stress specified in EFDC. Floods bring additional particulate load and/or serve to scour resident materials. Although this may be true to some extent there is no doubt that vegetation plays an significant role in the process and may in fact represent the dominant governing factor. The MFD provides no indication that this possibility has been considered. e.g Consider the following; is it possible that the floodplain sedimentary deposit is essentially in equilibrium with a wide range of flows including those occurring during floods and that the majority of the contaminant exchange process is governed by resident flora ? During floods PCB laden sediments are carried over the floodplain and are trapped within the understory and as a surface coating on leaves, stems, and fronds. Some fraction of these PCBs are incorporated into the sediment column but the majority remain mobile to be progressively washed from the surface of the floodplain by subsequent rainfall events - independent of river stage. Even some portion of the contaminants bound within the sediment column are taken up by plants and leave as a fraction of the detrital load in the fall and winter. Sediment transport plays a minor, secondary, role in the overall transport process serving only as the initial source.

Such a view has profound implications relative to modeling and ultimately remediation and seemingly warrants discussion.

c. ***Are the models adequate for describing the impacts of rare flood events?***

Given the weakness of the process discussion in the MFD this remains to be seen. Fundamentally the models appear adequate to numerically simulate the impacts of the rare flood event. But their ability to do so accurately is uniquely dependent on the algorithms used to detail impacts (cause and effect relationships) and the data available for calibration and verification. At the moment the combination appears best able to establish the effects of floods on system hydrodynamics -stage, velocity and boundary shear - at least within the main stem of the River. I'm less confident of model ability to simulate sediment transport process leading to an accurate specification of mass flux. HSPF should provide a reasonably accurate indication of the boundary flux of suspended materials during a high flow event. Here the issue may be only one of data adequacy for verification. The ability to model bed-load transport across the boundary and within and through the PSA however, remains an open question which the MFD indicates is "under investigation". Similarly, the MFD recognizes the importance of meandering but provides no indication of just how this process is to be treated (p.3-40).

d. ***Are the models adequate for discriminating between water-related and sediment-related sources of PCBs to fish and other biota?***

This is a subject outside of my area of expertise.

3. Again, based upon the technical judgment of the Panel, are the spatial and temporal scales of the modeling approaches adequate to address the principal need for the model - producing sufficiently accurate predictions of the time to attain particular PCB concentrations in environmental media under various scenarios (including natural recovery and different potential active remedial options) to support remedial decision-making in the context described above in the Background section? If not, what levels of spatial and temporal resolutions are required to meet this need?

The proposed models are able to accommodate a range of spatial and temporal scales sufficient to accurately simulate PCB fate and transport and system response to a variety of remedial options. I would like to see a more detailed justification for the spatial scales selected for segmentation as well as the longstream extent of the model. I'm willing to exclude the Pittsfield area from the model domain if there is clear indication that the effects of the ongoing remediation is being carefully monitored and that the results will be incorporated in the definition of source and the specification of the functional relationship between streamflow and PCB concentrations used to establish the upstream boundary conditions. As for the downstream boundary it seems advisable to extend the model domain in the interest of efficiency and recognition of future needs. If there are administrative reason why this is impractical and one only considers model function, Woods Pond and the bounding dam represent acceptable boundaries supported by a relatively long-term data set.

As for the scale of the individual model element or grid, The MFD fails to provide a process based discussion of the criteria used in the selection/specification of grid size. As discussed above, this might include analysis of the spatial distributions of sediment/PCB along and across selected cross-sectional transects. I was unable to extract this information from the data plots and suspect that it is not available. In the absence of such detailing it is impossible to evaluate the adequacy of the specified spatial scales.

4. Is the level of theoretical rigor of the equations used to describe the various processes affecting PCB fate and transport, such as settling, resuspension, volatilization, biological activity, partitioning, etc., adequate, in your professional judgment, to address the principal need for the model (as defined above)? If not, what processes and what resolution are required?

The theoretical rigor of the algorithms used in each of the component models is adequate and sufficiently flexible to accommodate a wide range of processes.

5. What supporting data are required for the calibration/validation of the model on the spatial and temporal scales necessary to address the principal need for the model (as defined above)? What supporting data are required to achieve the necessary level of process resolution in the model?

As discussed above, the modeling exercise would immediately benefit from the addition of time series observations detailing the response of the sediment transport system at a number of locations throughout the PSA and under a range of streamflows. These data in combination with the radionuclide analyses of longterm deposition rates would permit quantitative evaluation of the structure and form of the sediment water interface as well as definition of critical erosion conditions. This combination would significantly improve the quality of the sediment transport model and the accuracy of the associated PCB fluxes.

In addition to the time series observations, the model effort would benefit from more detailed analysis of the spatial patterns of the sediment/PCB distributions. The majority of the available data appear to have been obtained on a fixed grid (e.g. three stations spanning the channel) and not intended to detail spatial variability. Absent these data it's impossible to evaluate the adequacy of the proposed model segmentation.

6. Based upon your technical judgment, are the available data, together with the data proposed to be obtained by EPA, adequate for the development of a model that would meet the above referenced purposes? If not, what additional data should be obtained for these purposes?

See Above

III. Specific Comments on the Modeling Framework Design Report and/or the Quality Assurance Project Plan.

Overall these reports are reasonably well written and clear. Given the complexity of the issue and the number of authors involved this represents a major accomplishment. All responsible are to be complimented.

IV. Concluding Comments

As stated previously this is an ambitious effort. The EPA and its Modeling Team have made an impressive start. There is real promise that their efforts to establish a basis sufficient to permit quantitative evaluations of the factors governing PCB fate and transport in the Housatonic River and to design an optimum remedial plan can succeed. Success however, requires careful development of a logical model framework and the continuing acquisition of supporting data. The required framework would increase in complexity as our understanding of processes governing PCB fate and transport in the PSA increases. There is some indication that this fact has been lost sight of in the development of the MFD and that the proposed multi-component model is un-necessarily complex, on the one hand, while neglecting fundamental processes on the other. The absence of a clear indication of a "walk before running" philosophy leads to the suspicion that the emphasis here is on the modeling exercise rather than on the adequacy and accuracy of the model output. This impression is best corrected by a careful process based discussion of the PCB transport and fate in the Housatonic using all available data and an honest critical evaluation of knowns and unknowns. My review suggests that such a presentation would result in the proposal of a far simpler modeling scheme. Alternatively, this evaluation would lead to additional process driven field sampling to test a variety of carefully structured hypotheses .